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UV Written 2×8 Optical Power Splitter for FTTH Applications

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Abstract: Silica based integrated optical 2×8 power splitters are reported for the first time using UV-writing waveguide fabrication technology. High performance, compactness and low production costs make these components well suited for deployment in FTTH networks.

OCIS codes: (230.1360) Beam splitters; (130.3120) Integrated optics devices; (250.5300) Photonic integrated circuits; (160.5320) Photorefractive materials; (230.7390) Waveguides, planar; (260.7190) Ultraviolet.

1. Introduction

Low cost integrated optical 2×8 power splitters are important components for Fiber-To-The-Home (FTTH) applications since passive optical networks require splitters with double input to create a redundant path and increase the network security [1]. Hence the present work has focused on the development of such components by means of direct writing with a focussed UV laser beam in photosensitive glass samples [2], where costly photolithographic and etching processes are avoided.

We report on the fabrication of a number of 2×8 broadband splitters consisting of a broadband coupler and Y-branch splitter sections. The layout has been optimized for compactness and low loss. Performance in terms of loss and uniformity are nearly within commercial specifications in the wavelength range 1300-1750 nm.

2. Fabrication

The splitters are fabricated in three layer silica-on-silicon samples with a 5.4 μm thick, Ge/B doped core layer. The samples are loaded with deuterium at 500 bar until saturation prior to UV writing to enhance the photosensitivity. Channel waveguides are written into the core layer by scanning the sample under a continuous-wave, focused UV beam using high-precision translation stages [3]. The stages are computer controlled with an interferometric position measurement feedback loop. The UV beam has a wavelength of 257 nm and may be blocked using a shutter as required in the scanning process. The incident beam power is 45 mW, which is focused on the core layer to a $1/e^2$ spot size of 3.1 μm. After UV writing the samples are annealed at 80 °C for 12 hours to outdiffuse residual deuterium, then subjected to a second annealing at 320 °C for 3 hours to reduce the index step so that single mode operation is achieved in the 1300 nm and 1500 nm windows and the thermal stability is increased. Most of the circuit is written with a scan velocity of 280 μm/s, which yields a waveguide width of 6.1 μm and an index step after annealing of 0.0085.

3. Design and layout

The layout of the fabricated 2×8 splitters is depicted in Fig. 1(a). Two input channels are combined through an asymmetrical broadband directional coupler [4], which is written in two scans. An asymmetric structure in the central coupling region with a wavelength flattened response is achieved by locally decreasing the scan velocity in the first arm while increasing it in the second arm. It has been found experimentally that scan velocities of 100 μm/s and 900 μm/s, a center-to-center waveguide separation of 8 μm and 230 μm long waveguides in the central coupling region results in a wavelength flattened coupling ratio of 50%.

Each Y-branch section is written in three scans, first an access waveguide followed by two output arms (Fig. 1(b)). The output arms are shaped as a cascade of two S-bends: the first to make an adiabatic taper and the second to achieve the required transverse displacement for connecting to the next section. Each S-bend is shaped as a polynomial function with zero derivatives up to the fourth order in the ends. This minimizes mode mismatching which is typical of other curve types such as the circular arcs [3] or cosine bends previously deployed [5], thereby

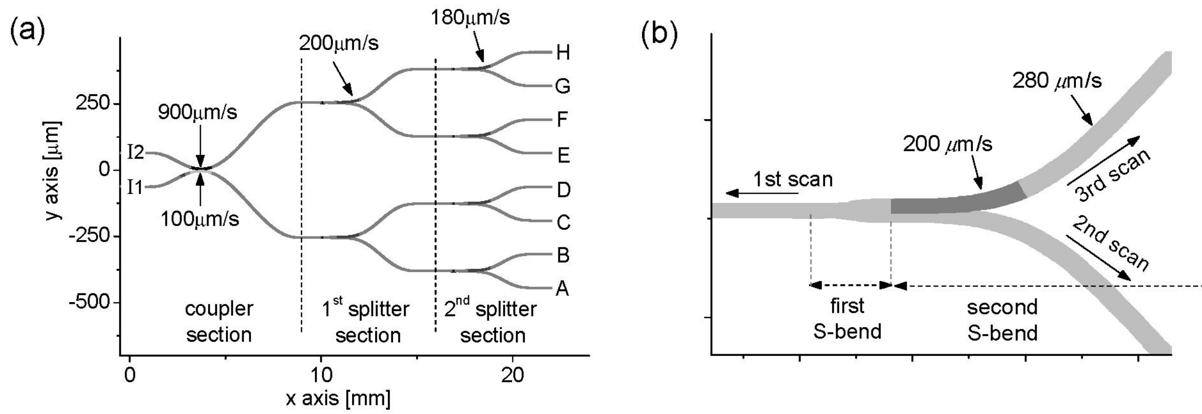

Fig. 1. (a) Overview of 2×8 splitter layout. (b) Close-up view of a Y-branch in 1st splitter section

reducing excess loss and improving the channel uniformity. The bend lengths have been chosen so that the minimum radius of curvature is 20 mm, yielding a measured excess loss below 0.03 dB/bend. Symmetrical splitting is achieved by applying slightly different scan velocities in the central part of each splitter (as indicated in Fig. 1), to compensate for a reduced photosensitivity in the vicinity of a UV exposed area [3].

The output port pitch is 127 μm to accommodate commercially available fiber connector arrays. The component is 22 mm long which, combined with 12 mm long fiber arrays, yields a pigtailed device that would be roughly 2/3 the size of many commercial components, and thus very well suited for compact system integration. The total UV writing time for a single 2×8 splitter is 360 seconds.

4. Performance

Characterization was carried out using butt-coupled SMF-28 fibers with index-matching oil. The performance of a typical 2×8 splitter measured at 1557 nm with a polarized source is summarized in Fig. 2. The dataset for each input port overlap each other and does not exhibit any slope, showing that the coupling and splitter sections are well balanced. The channel loss is <11.6 dB and the total excess loss is 1.4 dB, which is similar to that of commercial devices.

The average PDL is 0.7 dB, but for channel H it rises to 2 dB with excitation at I1. This phenomenon is seen in many of the fabricated devices, and it does not occur for the same input/output channel each time. The effect only becomes apparent when the guided mode amplitude is low, such as when the input signal is distributed among several output channels [5]. It is speculated that weakly guided higher order modes co-propagating in the core layer, upon re-coupling to the main mode leads to the observed behavior. A core layer with a refractive index slightly lower than that of the buffer/cladding may greatly reduce the amplitude of co-propagating higher order modes and thus reduce the sporadically high PDL.

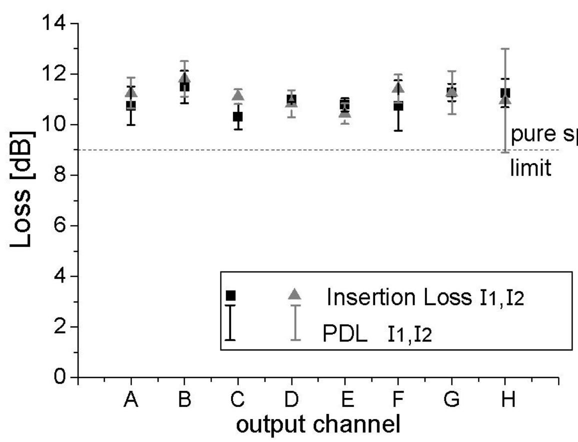

Fig. 2. Insertion loss (symbols) and PDL (vertical bars) of a 2×8 splitter at 1557 nm measured for both input ports

Broadband characterization was done with a unpolarized source from 1300-1750 nm. The spectral variation of an isolated asymmetric coupler section is depicted in Fig. 3(a) along with that of a standard symmetrical coupler for comparison. The former exhibits a ±0.5 dB flatness over the entire wavelength range, while the symmetrical coupler exhibits the same variation over just 80 nm. Broadband measurements of channel loss, uniformity and total excess loss of a complete 2×8 splitter is shown in Fig. 3(b). The total excess loss over the entire range is 1.6 dB with a ripple of ±0.2 dB. The uniformity is quite flat and low down to 1400 nm, with a mean value of 1.9 dB and a ripple of ±0.4 dB. Below 1400 nm the uniformity rises, most likely due to the increased slope of the coupling ratio shown in

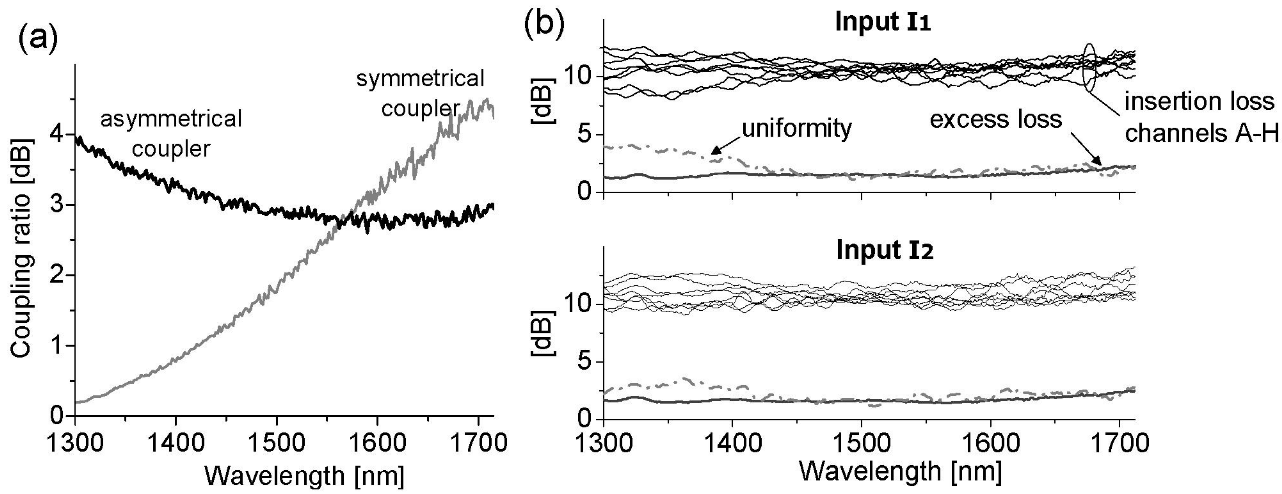

Fig. 3. (a) Spectral variation of isolated coupler (black curve: asymmetrical coupler, grey curve: symmetrical coupler). (b) Broadband measurement of channel insertion loss (black curves), channel uniformity (grey dot-dashed curve) and total excess loss (dark grey curve) for a 2×8 splitter.

Fig. 3(a). The overall broadband response is similar to top-grade commercial performance both in terms of loss and uniformity in the C, L and E bands. A further improvement of the uniformity can be achieved in the 1300 nm window by a small optimization of the coupling section, i.e. by shifting the wavelength of the peak coupling ratio from the current ~1600 nm to ~1500 nm. The degree of broadband operation demonstrated here is achieved due to the combination of an asymmetric coupler design with inherently broadband Y-shaped splitting sections.

The device-to-device fabrication reproducibility is quite good on our research setup with 5 out of 7 measured devices being within the presented specifications. The main source of component failure stems from laser power drift, which is expected to be improved by introduction of an active control of the incident UV power.

5. Conclusion

The first demonstration of 2×8 power splitters made by direct UV writing has been presented. The splitter layout consists of a broadband coupler section followed by Y-branch splitter sections and has been optimized for compactness and low loss. The unique feature of direct UV writing to locally control the index step and width by changing the scan velocity has been exploited to achieve broadband performance. The scan velocities applied in the splitting sections have been optimized to achieve good uniformity among the output channels. The components, showing good performance in terms of loss, uniformity and bandwidth, could find application in FTTH networks.

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